CLAIMS

What is claimed is:

1. A scanning probe microscope comprising:

a cantilever;

a first tip mounted on the cantilever; and

a second tip mounted on the cantilever, the first and the second tips being configured to combine to form an imaging probe and to separate to form a manipulation probe.

2. The scanning probe microscope according to claim 1, wherein the first and the second tips are configured to form a first position characterized in that the tips combine to form an imaging tip, and

wherein the first and the second tips are configured to form a second position characterized in that the tips separate to manipulate particles on a surface of a sample.

3. The scanning probe microscope according to claim 2, wherein the tips are configured to form the first position when a voltage is applied across the tips.

4 The scanning probe microscope according to claim 1, further comprising:

a first electrode coupled to the first tip; and

a second electrode coupled to the second tip.

5. The scanning probe microscope according to claim 4, wherein the tips are configured to form the first position when a voltage is applied across the first electrode and the second electrode.

6. The scanning probe microscope according to claim 1, wherein the cantilever comprises:

a first cantilever portion, wherein the first tip is mounted on the first cantilever portion; and

a second cantilever portion, wherein the second tip is mounted on the second cantilever portion.

7. The scanning probe microscope according to claim 6, further comprising:

a first electrode coupled to the first cantilever portion; and

a second electrode coupled to the second cantilever portion.

8. The scanning probe microscope according to claim 7, wherein the tips are configured to form the first position when a voltage is applied across the first electrode and the second electrode.

9. A scanning probe microscope comprising:

a cantilever having a longitudinal axis;

a first tip mounted on the cantilever substantially perpendicular to the longitudinal axis; and

a second tip mounted on the cantilever substantially perpendicular to the longitudinal axis.

10. The scanning probe microscope according to claim 9, wherein the cantilever comprises:

a first cantilever portion, wherein the first tip is mounted on the first cantilever portion; and

a second cantilever portion, wherein the second tip is mounted on the second cantilever portion.

11. The scanning probe microscope according to claim 10, further comprising:
a first electrode coupled to the first cantilever portion; and
a second electrode coupled to the second cantilever portion.

12. The scanning probe microscope according to claim 11, wherein the tips are configured to combine by applying a voltage across the first electrode and the second electrode.

13. The scanning probe microscope according to claim 9, wherein the tips are configured to combine to scan a surface of a sample to create an image of the surface of the sample.

14. The scanning probe microscope according to claim 13, wherein the tips are configured to combine by applying a voltage across the first tip and the second tip.

15. The scanning probe microscope according to claim 13, wherein the tips are configured to combine by applying a voltage across the first cantilever portion and the second cantilever portion.

16. The scanning probe microscope according to claim 9, further comprising:
a first electrode coupled to the first tip; and
a second electrode coupled to the second tip.

17. The scanning probe microscope according to claim 16, wherein the tips are configured to combine by applying a voltage across the first electrode and the second electrode.

18. A nanomechanical tweezing apparatus comprising:
a cantilever having a first cantilever portion and a second cantilever portion;

a first tip coupled to the first cantilever portion;

a second tip coupled to the second cantilever portion;

a first electrode coupled to the first cantilever portion; and

a second electrode coupled to the second cantilever portion,

wherein the first cantilever portion and the second cantilever portion are configured so that the first tip and the second tip squeeze into contact when a sufficient voltage is applied across the first electrode and the second electrode,

wherein the first tip and the second tip are configured to grip microscopic material, and

wherein the first tip and the second tip are also configured to form a single imaging stylus when they are squeezed into contact.

19. The nanomechanical tweezing apparatus according to claim 18, wherein the first tip is coupled substantially perpendicular to a longitudinal axis of the first cantilever portion and the second tip is coupled substantially perpendicular to a longitudinal axis of the second cantilever portion.

20. A method for interacting with a surface of a sample comprising:

scanning the surface of the sample with a probe operating at a first deflection setpoint;

removing the probe from the surface of the sample;

turning off a feedback used to maintain probe operation at the first deflection setpoint;

storing a change in deflection between the first deflection setpoint and a first free air deflection;

changing a feedback type from deflection to amplitude; and

turning on the feedback of the probe.

21. The method according to claim 20, further comprising switching between amplitude mode and contact mode by:

turning off the feedback of the probe;

setting a second deflection setpoint based on a second free air deflection and the change in deflection;

changing a feedback type from amplitude to deflection; and

turning on the feedback of the probe.

22. The method according to claim 20, further comprising manipulating the surface with the probe.

23. The method according to claim 20, wherein the probe comprises:

a cantilever;

a first tip mounted on the cantilever; and

a second tip mounted on the cantilever, the first and the second tip being configured to combine to form an imaging tip.

24. The method according to claim 23, further comprising applying a voltage across the first tip and the second tip to combine the first tip and the second tip to form an imaging tip.

25. A method for operating a probe that interacts with a surface of a sample, comprising:

scanning a region of the surface of the sample with the probe;

manipulating the sample with the probe; and

rescanning a subregion of the region of the surface of the sample.

26. The method for operating a probe that interacts with a surface of a sample according to claim 25, wherein the manipulating step further comprises manipulating the

sample with a probe other than the probe used to scan the region of the surface of the sample.

27. The method for operating a probe that interacts with a surface of a sample according to claim 25, wherein the manipulating step further comprises manipulating the sample with the probe used to scan the region of the surface of the sample.

28. The method for operating a probe that interacts with a surface of a sample according to claim 27, wherein

the manipulating step further comprises manipulating the subregion of the region of the sample with the probe, and

the rescanning step further comprises rescanning the manipulated subregion of the region of the sample.

29. The method for operating a probe that interacts with a surface of a sample according to claim 27, wherein the manipulating step further comprises manipulating particles of the sample with the probe.

30. The method for operating a probe that interacts with a surface of a sample according to claim 27, wherein the manipulating step further comprises manipulating particles of the sample by picking up the particles with the probe.

31. The method for operating a probe that interacts with a surface of a sample according to claim 25, wherein the probe comprises:

a cantilever;

a first tip mounted on the cantilever; and

a second tip mounted on the cantilever, the first and the second tips being configured to combine to form an imaging probe.

32. The method for operating a probe that interacts with a surface of a sample according to claim 31, further comprising applying a voltage across the first tip and the second tip to combine the first tip and the second tip to form an imaging probe.

33. A method for interacting with a surface of a sample, comprising:

scanning the surface of the sample with a probe to create a first image;

scanning the surface of the sample with a probe to create a second image;

determining a relative position of the probe by comparing the first image to the second image; and

manipulating the sample with the probe.

34. The method for interacting with a surface of a sample according to claim 33, further comprising adjusting a position of the probe based on the determining step.

35. The method for interacting with a surface of a sample according to claim 33, wherein the probe comprises:

a cantilever;

a first tip mounted on the cantilever; and

a second tip mounted on the cantilever, the first and second tips being configured to combine to form an imaging probe.

36. The method for interacting with a surface of a sample according to claim 35, further comprising applying a voltage across the first tip and the second tip to combine the first tip and the second tip to form the imaging probe.

37. A method for interacting with a surface of a sample, comprising:

scanning the surface of the sample with a probe to create an image;

performing pattern recognition on the image to obtain a pattern recognized image; and

automatically manipulating the surface of the sample with the probe based on the pattern recognized image.

38. The method for interacting with a surface of a sample according to claim 37, wherein the probe comprises:

a cantilever;

a first tip mounted on the cantilever; and

a second tip mounted on the cantilever, the first and second tips being configured to combine to form an imaging tip.

39. The method for interacting with a surface of a sample according to claim 38, further comprising applying a voltage across the first tip and the second tip to combine the first tip and the second tip to form an imaging tip.

40. A method of making a nanomechanical tweezing apparatus, comprising:

forming a probe including a tip extending from a cantilever, the probe having a longitudinal axis; and

performing milling substantially along a longitudinal axis of the probe to separate the probe into a first cantilever including a first tip and a second cantilever including a second tip.

41. The method according to claim 40, wherein the performing step performs focused ion beam milling substantially along the longitudinal axis of the probe to separate the probe into a first cantilever including a first tip and a second cantilever including a second tip.

42. The method according to claim 40, further comprising:

coupling a first electrode to the first cantilever portion; and

coupling a second electrode to the second cantilever portion.

43. The method according to claim 40, wherein the probe comprises a combination of silicon and silicon dioxide.

44. The method according to claim 40, further comprising performing metal deposition on a surface of the probe.

45. A method of making a probe for a scanning probe microscope, comprising:

forming a first cantilever portion;

forming a second cantilever portion substantially parallel to the first cantilever portion;

forming a first tip portion on the first cantilever portion substantially perpendicular to the first cantilever portion; and

forming a second tip portion on the second cantilever portion substantially perpendicular to the second cantilever portion.

46. The method of making a probe for a scanning probe microscope according to claim 45, further comprising:

coupling a first electrode to the first cantilever portion; and

coupling a second electrode to the second cantilever portion.

47. The method of making a probe for a scanning probe microscope according to claim 45, further comprising:

forming a layer of insulation on the first and second cantilever portions and on the first and second tip portions; and

forming a layer of a conductive material over the layer of insulation material on a surface of the first and second cantilever portions and on the tip portions.

48. The method of making a probe for a scanning probe microscope according to claim 47, wherein the first tip portion and the second tip portion are used to manipulate a sample.

49. The method of making a probe for a scanning probe microscope according to claim 47, wherein the first and second cantilever portions comprise silicon, the layer of insulation comprises silicon dioxide, and the layer of conductive material comprises metal.

50. An assembly comprising:

an actuator with a longitudinal axis having a fixed end, and a free end configured to translate in at least one direction with respect to the fixed end;

a multiple bar linkage having first and second links mutually constrained to translate with respect to each other, and wherein the first link is fixed to a reference structure and the second link is constrained to translate in a direction generally parallel to the longitudinal axis of the actuator;

a coupling having first and second ends, the first end being fixed to the actuator proximate to its free end, and the second end being fixed to the second link, the coupling adapted to transmit displacement in a direction substantially parallel to the longitudinal axis of the actuator;

an objective fixed to the reference structure, wherein the objective is between a light source and a position sensor, and the position sensor measures displacement of the objective in at least one direction generally perpendicular to the longitudinal axis of the actuator; and

a probe coupled to the multiple bar linkage, wherein the probe is configured to manipulate the surface of a sample.

51. The assembly according to claim 50, wherein the light source and the position sensor are stationary.

52. The assembly according to claim 50, wherein the objective further comprises a set of microlenses.

53. The assembly according to claim 52, wherein the set of microlenses provide optical magnification to increase a signal-to-noise ratio.

54. The assembly according to claim 53, wherein the magnification is

$$M = 1 + i/o$$

wherein i is an orthogonal distance from the principal plane of the set of microlenses to the position sensor and o is an orthogonal distance from the principal plane of the set of microlenses to the light source.

55. The assembly according to claim 54, wherein movement of a beam of electromagnetic radiation from the light source directed to the position sensor through the set of microlenses is multiplied by a factor of M.

56. The assembly according to claim 50, wherein the assembly is a scanning probe microscope.

57. The assembly according to claim 50, wherein the actuator is a piezoelectric or electrostrictive actuator.

58. The assembly according to claim 50, wherein the probe comprises

a cantilever;

a first tip mounted on the cantilever; and

a second tip mounted on the cantilever, the first and the second tip being configured to combine to form an imaging tip.

59. The assembly according to claim 58, wherein a voltage is applied across the first tip and the second tip to combine the first tip and the second tip to form an imaging tip.

60. A scanning probe microscope for imaging and manipulating a sample comprising:

a first tip;

a second tip; and

an actuator coupled to the first tip, the actuator being configured to adjust the position of the first tip to a first position for imaging the sample with the scanning probe microscope and to adjust the position of the first tip to a second position for manipulating the sample with the scanning probe microscope.

61. The scanning probe microscope according to claim 60, further comprising a base, wherein the first tip is coupled to the base and the second tip is coupled to the base.

62. The scanning probe microscope according to claim 60,

wherein the first tip comprises an imaging tip and the second tip comprises a manipulation tip, and

wherein the actuator is configured to adjust the position of the imaging tip to an imaging position for imaging the sample with the imaging tip and the actuator is configured to adjust the position of the imaging tip away from the sample for manipulating the sample with the manipulation tip.

63. The scanning probe microscope according to claim 60,

wherein the first tip comprises a manipulation tip and the second tip comprises an imaging tip, and

wherein the actuator is configured to adjust the position of the manipulation tip to a manipulation position for manipulating the sample with the manipulation tip and the

actuator is configured to adjust the position of the manipulation tip away from the sample for imaging the sample with the imaging tip.

64. The scanning probe microscope according to claim 60, wherein the actuator adjusts the position of the first tip in response to at least one of a voltage differential applied to the actuator and a thermal differential applied to the actuator.

65. A method for interacting with a surface of a sample comprising:

scanning the surface of the sample with a probe;

removing the probe from the surface of the sample;

turning off a feedback of the probe;

storing a change in amplitude between an amplitude setpoint and a free air amplitude; and

turning on the feedback of the probe.

66. The method according to claim 65, further comprising switching between contact mode and amplitude mode by:

turning off the feedback of the probe;

setting an amplitude setpoint based on a free air amplitude combined with a change in amplitude;

changing the input to the feedback from deflection to amplitude; and

turning on the feedback of the probe.

67. The method according to claim 65, further comprising manipulating the surface with the probe.

68. The method according to claim 65, wherein the probe comprises:

a cantilever;

a first tip mounted on the cantilever; and

a second tip mounted on the cantilever, the first and the second tip being configured to combine to form an imaging tip.

69. The method according to claim 68, further comprising applying a voltage across the first tip and the second tip to combine the first tip and the second tip to form an imaging tip.

70. A method for interacting with a surface of a sample comprising:

scanning the surface of the sample with a probe operating at a first deflection setpoint;

removing the probe from the surface of the sample;

turning off a feedback used to maintain probe operation at the first deflection setpoint; and

storing a change in deflection between the first deflection setpoint and a first free air deflection.

71. A probe assembly comprising:

a U-shaped cantilever including at least two generally parallel arms; and

an integrated tip on each arms,

wherein each arms contain an actuating element for independent control of each the arms.

72. A probe assembly comprising:

a first probe including a first tip; and

a second probe including a second tip;

wherein the probes are configured to independently move vertically with an application of an electrostatic force.

73. The probe assembly according to claim 72, further comprising a common base, wherein the first probe and the second probe both extend from the common base.